

## CIRCUIT AND METHOD FOR REDUCING NOISE INTERFERENCE IN DIGITAL DIFFERENTIAL INPUT RECEIVERS

### TECHNICAL FIELD

This invention relates to digital differential input circuits for memory  
5 devices and other electronic devices, and, more particularly, to a method and circuit that  
makes such circuits relatively immune to noise.

### BACKGROUND OF THE INVENTION

Digital electronic devices, such as memory devices, communicate with  
external circuitry through input terminals, output terminals, and input/output terminals.  
10 These input/output terminals are bi-directional, *i.e.*, digital input signals may be applied  
to the same terminal to which digital output signals are applied, although not at the  
same time. One type of input circuit to which input signals are initially applied is a  
digital differential receiver 10a, an example of which is shown in Figure 1. The  
differential receiver 10a includes a pair of NMOS transistors 14, 16 having their sources  
15 coupled to a common node 20. The common node 20 is, in turn, coupled to ground  
through a NMOS current sink transistor 24 that is biased ON by coupling the gate of the  
transistor 24 to a suitable bias voltage. A pair of load impedances 30, 32 are coupled  
between the drains of the respective transistors 14, 16 and a power supply voltage  $V_{CC}$ .  
The load impedances 30, 32 may be implemented by a variety of circuit components,  
20 such as resistors (not shown) or transistors (not shown). Differential output signals are  
generated at output nodes 34, 35 between the drains of respective transistors 14, 16 and  
the load impedances 30, 32. Alternatively, a single-ended output signal may be  
generated at either one of the output nodes 34, 35. The differential output signals or the  
single-ended output signal are applied to circuitry internal to an electronic device (not  
25 shown), such as a memory device.

The gate of one transistor 14 is coupled to a first input terminal 36,  
which is, in turn, coupled to a voltage reference source 40. The gate of the other  
transistor 16 is coupled to a second input terminal 38, which is, in turn, coupled to an

externally accessible terminal 44a. As shown in Figure 1, the reference voltage source 40 is also coupled to a plurality of other input receivers 10b,c...n that are coupled to respective externally accessible terminals 44b,c . n. If the terminal 44a is also an output terminal, *i.e.*, the terminal 44a is an input/output terminal, the terminal 44a is also coupled to the output of an output driver 50. An input of the output driver 50 is coupled to circuitry internal to an electronic device (not shown).

In operation, a digital input signal is applied to the gate of the transistor 16 through the terminal 44a. The magnitude of the input signal is compared to the magnitude of the reference voltage applied to the gate of the transistor 14. If the magnitude of the input signal is greater than the magnitude of the reference voltage, the output signal(s) are considered to be at one logic level. If the magnitude of the input signal is less than the magnitude of the reference voltage, the output signal(s) are considered to be at a different logic level.

One problem that is often encountered with the input receiver 10 of Figure 1 results from noise signals present in the reference voltage. Noise signals momentarily increase or decrease the magnitude of the reference voltage, thereby altering the voltage at which a transition of the input signal from one logic level to another is detected. Consequently, the timing of transitions of the output signal from the input receiver 10 responsive to transitions of the input signal can vary in an unpredictable manner. An electronic device containing the input receivers 10 must therefore operate with looser timing tolerances, thereby reducing the operating speed of the electronic device.

Noise signals can be coupled to the reference voltage source 40 by several means. For example, output signals from the output driver 50a can be coupled through the input receiver 10a to the reference voltage source 40. More specifically, since the transistors 14a, 16a will generally be biased to their conductive operating range, transitions of an output signal from the output driver 50a applied to the gate of the transistor 16a can be coupled to the common node 20a, and from the common node 20a to the gate of the transistor 14a. These noise signals resulting from the transitions of the output signal are then coupled to the gates of transistor 14b,c...n in the other

input receivers 10b,c...n. One or more of these other input receivers 10b,c...n may be receiving an input signal via its respective terminal 44b,c...n at the same time the output driver 50a is applying an output signal to its respective terminal 44a. For example terminals 44b,c may be receiving signals corresponding to bits of an address at  
 5 the same time the terminal 44a is outputting a signal corresponding to a bit of data. As a result, the timing with which these input receivers 10b,c...n respond to transitions of input signals can vary in an unpredictable manner.

The noise signals generated in this manner could be reduced significantly by providing each input receiver 10a,b,c,...n with its own dedicated reference voltage  
 10 source 40, but doing so might significantly increase the size and cost of integrated circuits using such input receivers 10 because of the large number of terminals 44 typically provided for many integrated circuits.

There is therefore a need for a cost effective method and circuit for making digital differential input receivers 10 more immune to noise generated by  
 15 respective output drivers 50 coupled to one or more of the terminals 44.

## SUMMARY OF THE INVENTION

The present invention is a method and circuit for protecting a reference voltage source from noise generated by applying an output signal to an input/output terminal. The input/output terminal is also coupled to an input receiver that is also  
 20 coupled to the reference voltage source so that the input receiver can serve as a conduit for coupling transitions of the output signal to the reference voltage source. An output signal detector detects when the output signal is being applied to the input/output terminal. An isolation circuit responds to the output signal being detected by isolating the reference voltage source from the input/output terminal to which the output signal is  
 25 being applied. According to one aspect of the invention, the isolation circuit is coupled between the input receiver and either the input/output terminal or the reference voltage source. Signals are coupled through the isolation circuit when the output signal is not detected, and signals are substantially blocked from passing through the isolation circuit when the output signal is detected. In another aspect of the invention, the isolation

circuit comprises a bias circuit that biases the input receiver to a condition that substantially reduces coupling from the input/output terminal to the reference voltage source responsive to the output signal being detected.

#### BRIEF DESCRIPTION OF THE DRAWINGS

5           Figure 1 is a schematic diagram of a plurality of prior art digital differential input receivers that are coupled to respective signal terminals, which are also coupled to respective output drivers.

          Figure 2 is a block diagram of a plurality of digital differential input receivers according to one embodiment of the invention.

10           Figure 3 is a block diagram of a plurality of digital differential input receivers according to another embodiment of the invention.

          Figure 4 is a logic diagram of a digital differential input receiver according to still another embodiment of the invention.

          Figure 5 is a block diagram of a plurality of digital differential input  
15 receivers according to another embodiment of the invention.

          Figure 6 is a block diagram of a memory device using a digital differential input receiver in accordance with of one embodiment of the invention.

          Figure 7 is a block diagram of a computer system using the memory device of Figure 6.

#### 20 DETAILED DESCRIPTION OF THE INVENTION

          One embodiment of a circuit that is capable of making the input receiver  
10 more immune to noise signals is shown in Figure 2 in which components common to Figures 1 and 2 have been provided with the same reference numerals. In addition to the components of the input receiver 10 shown in Figure 1, each input receiver circuit  
25 60 in the embodiment of Figure 2 includes an output signal detector 62 that detects when its respective output driver 50 is applying an output signal to its respective terminal 44. The output signal detector 62 then generates an ACTIVATE signal that is applied to an isolation circuit 66 coupled between the terminal 44 and the second input

terminal 38. Although the input receiver circuit 60 shown in Figure 2 uses an input receiver 10 of the type shown in Figure 1 in which the second input terminal 38 is coupled to the gate of the transistor 16, other designs for an input receiver may be used.

The output signal detector 62 may perform its function using a variety of techniques. For example, each of the output drivers 50 may be adapted to produce an appropriate signal when the output driver 50 is active, and the output signal detector 62 may then detect such signal and generate the activate signal responsive thereto. By way of further example, each output signal detector 62 may alternatively be adapted to detect output signals generated by its respective output driver 50, and generate the ACTIVATE signal in response thereto.

Regardless of how the output signal detector 62 generates the ACTIVATE signal, the isolation circuit 66 responds to the ACTIVATE signal by isolating the terminal 44 from the second input terminal 38. At all other times, the isolation circuit 66 is operable to couple the terminal 44 to the second input terminal 38 so the input receiver 10 can respond to input signals. As a result, output signals applied to the terminal 44 by the output driver 50 cannot be coupled through the input receiver 10 to the reference voltage source 40.

Another embodiment of an input receiver circuit 70 according to the invention is shown in Figure 3. The input receiver 70 is identical to the input receiver 60 of Figure 2 except the isolation circuit 66 is coupled between the reference voltage source 40 and the first input terminal 36. The output signal detector 62 generates the ACTIVATE signal when the output driver 50 generates an output signal, thereby causing the isolation circuit 66 to isolate the first input terminal 36 from the reference voltage source 40.

A more detailed embodiment of an input receiver circuit 80 according to the invention is shown in Figure 4 in which components of the input receiver circuit 80 that are identical to previously described components have been provided with the same reference numerals. The terminal 44 is coupled to a second input terminal 82 of a conventional digital differential input receiver 88, such as the input receiver 10 of Figure 1, through an NMOS transistor 94 and a first pass gate 96. Another input 90 of

the input receiver 88 is coupled to a reference voltage source 40, as previously explained. The NMOS transistor 94, which is biased ON by a pumped voltage  $V_{CCP}$  applied to its gate, is provided for the purpose of protecting the circuitry in the input receiver circuit 80 from electrostatically generated voltages applied to the terminal 44.

5 The terminal 44 is also coupled to a dummy load circuit 100 through the NMOS transistor 94 and a second pass gate 104. The dummy load circuit 100 is preferably formed by a circuit that is topographically similar to the input receiver 88 so that the input impedance of the input terminal 44 is the same when it is coupled to the dummy load circuit 100 as it is when it is coupled to the input receiver 88. The pass gates 96,  
10 104 are each formed in a conventional manner by an NMOS transistor 110 coupled in parallel with a PMOS transistor 112.

The second pass gate 104 is enabled by applying a high ACTIVATE signal to the NMOS transistor 110 of the pass gate 104 and a low ACTIVATE\* signal to the PMOS transistor 112 of the pass gate 104. The ACTIVATE signal is generated  
15 by coupling the ACTIVATE\* signal through an inverter 116. The first pass gate 96 is enabled by applying a low ACTIVATE signal to the NMOS transistor 110 of the pass gate 96 and a high ACTIVATE\* signal to the PMOS transistor 112 of the pass gate 96. The pass gates 96, 104 are thus alternately enabled, with the pass gate 104 being enabled by an active high ACTIVATE signal and the pass gate 96 being enabled by an  
20 inactive low ACTIVATE signal.

The ACTIVATE signal is generated by a NOR gate 120 formed in a conventional manner by 3 PMOS transistors 130, 132, 134 coupled in series with 3 NMOS transistors 140, 142, 144. The NOR gate 120 receives Q and QL input signals from an output driver (not shown), at least one of which is high when the output driver  
25 coupled to the terminal 44 is generating an output signal. A suitable output driver is shown and described in U.S. Patent Application Ser. No. \_\_\_\_\_ to Brian W. Huber *et al.*, entitled "METHOD AND SYSTEM FOR CONTROLLING THE SLEW RATE OF SIGNALS GENERATED BY OPEN DRAIN DRIVER CIRCUITS," which is incorporated herein by reference. A GLOBAL input to the NOR gate 120 is coupled to

the input receiver circuits 80 for all terminals 44 in a device to allow all of the input receivers 88 to be simultaneously isolated from their respective input terminals 44.

In operation, when Q, QL or GLOBAL is high, the NOR gate 120 outputs a low ACTIVATE\* signal and the inverter 116 outputs a high ACTIVATE  
 5 signal to cause the pass gate 96 to isolate the terminal 44 from the input receiver 88 and instead cause the pass gate 112 to couple the terminal 44 to the dummy load 100. When Q, QL and GLOBAL are all low, the NOR gate 120 outputs a high ACTIVATE\* signal and the inverter 116 outputs a low ACTIVATE signal to cause the pass gate 96 to couple the terminal 44 to the input receiver 88 and to cause the pass gate 112 to isolate  
 10 the terminal 44 from the dummy load 100. Therefore, whenever the terminal 44 is receiving an output signal from an output driver, the terminal 44 is isolated from the input receiver 88 so that transitions of the output signal cannot be coupled to the reference voltage source 40. Instead, the terminal 44 is then coupled to the dummy load 100 so the impedance at the terminal 44 remains the same. Whenever the terminal 44 is  
 15 not receiving an output signal from an output driver, the terminal 44 is coupled to the input terminal 82 of the input receiver 88.

Another embodiment of a digital differential input receiver 200 that is substantially immune from noise being generated at the reference voltage source 40 responsive to signals from the output driver 50 is shown in Figure 5. Instead of  
 20 externally isolating the reference voltage source 40 from the terminal 44, the input receiver 200 internally isolates the reference voltage source 40 from the terminal 44. More specifically, the ACTIVATE signal from the output signal detector 62 is coupled to a bias circuit 210 that outputs a predetermined bias voltage  $V_B$  responsive to the ACTIVATE signal. The predetermined voltage has a magnitude that is at least equal to  
 25 the voltages applied to the gates of the transistors 14, 16 less the threshold voltages  $V_T$  of the transistors 14, 16. As a result, when the ACTIVATE signal is generated, the transistors 14, 16 are biased out of their inversion region, thereby substantially preventing transient voltages generated by transitions of signals from the output driver 50 from being coupled to the reference voltage source 40. When the ACTIVATE signal  
 30 is not being generated, the output of the bias circuit 210 is tri-stated to a high impedance

so that it does not affect the operation of the input receiver 200. Thus, by isolating the terminal 44 from the reference voltage source 50 internally within the input receiver 10, the input receiver circuit 200 is rendered substantially immune to noise that would otherwise be generated responsive to transitions of signals from the driver circuit 50.

5           Although one means of internally isolating the terminal 44 from the reference voltage source 40 is shown in Figure 5, it will be apparent that other means are possible.

          A memory device in the form of a synchronous dynamic random access memory ("SDRAM") 300 that uses one or more input receivers 310 according to the  
 10   invention is shown in Figure 6. The SDRAM 300 typically receives both a row address and a column address through an address bus 314 that specify where data are to be transferred to or from within the SDRAM 300. The row and column addresses are initially applied to an address register 312. The addresses normally include a large number of address bits, and the address register 312 is typically coupled to the address  
 15   bus 314 through an externally accessible terminal 40 for each address bit. The address register 312 may include a digital differential input receiver, such as the input receiver 10 shown in Figure 1. If noise is coupled to a reference voltage source used in such input receiver 10, the SDRAM 300 may fail to properly register address signals.

          The row addresses received by the address register 312 are applied to a  
 20   row address multiplexer 318. The row address multiplexer 318 couples the row address to a number of components associated with either of two memory bank arrays 320, 322 depending upon the state of a bank address bit forming part of the row address. Associated with each of the arrays 320, 322 is a respective row address latch 326 that stores the row address, and a row decoder 328 that applies various signals to its  
 25   respective arrays 320 or 322 as a function of the stored row address. The row address multiplexer 318 also couples row addresses to the row address latches 326 for the purpose of refreshing the memory cells in the arrays 320, 322. The row addresses are generated for refresh purposes by a refresh counter 330 that is controlled by a refresh controller 332.



After the row address has been applied to the address register 312 and stored in one of the row address latches 326, a column address is applied to the address register 312. The address register 312 couples the column address to a column address latch 340. In a normal operating mode, the column address is coupled through a burst counter 342 directly from the column address latch 340 to an address buffer 344. However, in a burst operating mode, the burst counter 342 generates a sequence of column addresses starting at the column address applied to the burst counter 342 from the column address latch 340.

After a column address is applied from the burst counter 342 to the column address buffer 344 in either the normal mode or the burst mode, the column address buffer 344 applies the column addresses to a column decoder 348. As is well known in the art, the column decoder 348 applies various signals to respective sense amplifiers and associated column circuitry 350, 352 for the respective arrays 320, 322.

Data to be read from one of the arrays 320, 322 are coupled to the column circuitry 350, 352 for one of the arrays 320, 322, respectively. The data are then coupled to a data output register 356, which contains an output driver circuit (not shown in Figure 6) applies the data to a data bus 358 through data bus terminals 40. Data to be written to one of the arrays 320, 322 are coupled from the data bus 358 through the data bus terminals 40 and a data input register 360 to the column circuitry 350, 352 where they are transferred to one of the arrays 320, 322, respectively. A mask register 364 may be used to selectively alter the flow of data into and out of the column circuitry 350, 352, such as by selectively masking data to be read from the arrays 320, 322.

The data input register 360 includes a digital differential input receiver circuit 362, such as the input receiver circuit 80 shown in Figure 4 or the input receiver circuit 200 shown in Figure 5. As a result, when data signals are being output from the data output register 356 and transitions of the data signals are thus being applied to the data bus terminals 44, noise signals are not being coupled to the reference voltage source 40 for the input receiver 10 in the address register 312. The address register 312 is thus able to properly register address signals corresponding to address bits designating the location of data in the memory arrays 320, 322 that are to be read.

The above-described operation of the SDRAM 300 is controlled by a command decoder 368 responsive to high-level command signals received on control bus terminals 40 through a control bus 370. The command decoder 368 may also include an input receiver 40 that can fail to properly receive the command signals if noise is present on a reference voltage received from a reference voltage source. These high level command signals, which are typically generated by a memory controller (not shown in Figure 6), are a clock enable signal CKE\*, a chip select signal CS\*, a write enable signal WE\*, a row address strobe signal RAS\*, and a column address strobe signal CAS\*, which the "\*" designating the signal as active low. The command decoder 368 generates a sequence of control signals responsive to the command signals to carry out the function (e.g., a read or a write) designated by the command signals. These control signals, and the manner in which they accomplish their respective functions, are conventional. Therefore, in the interest of brevity, a further explanation of these control signals will be omitted. The high-level command signals are clocked into the command decoder 368 in synchronism with a clock signal CLK. The CLK signal, or internal clock signals (not shown) generated from the CLK signal, control the timing at which the control signals carry out their respective functions in the SDRAM 300. The control signals are preferably registered with both the rising and falling edges of the CLK signal (or corresponding internal clock signals) so that two operations are accomplished each period of the CLK signal. An SDRAM 300 operating in this manner is known as a "Double Data Rate DRAM."

The SDRAM 300 of Figure 6 may be used in a variety of applications, including in a computer system 400 as shown in Figure 7. The computer system 400 includes a processor 412 for performing various computing functions by executing software to perform specific calculations or tasks. The processor 412 is coupled to a processor bus 414 that normally includes an address bus, a control bus, and a data bus (not separately shown). The processor bus 414 is coupled to a system controller 420 or similar device, such as a memory controller, for controlling the transfer of data between the processor 412 and system memory 416. In the embodiment of Figure 7, the system memory 416 is implemented using the SDRAM 10 of Figure 6. The system controller

420 is coupled to the system memory 416 by an address bus 418 and a control bus 420. In the embodiment of Figure 7, a data bus 422 of the system memory 416 is coupled to the data bus of the processor bus 414, although the data bus 422 of the system memory 416 may be coupled to the processor 412 through the system controller 420 in the same  
5 manner as the address bus 418 and the control bus 420. Although the SDRAM 10 is used as the system memory 416, it will be understood the system memory 416 may be implemented by other types of memory devices, such as a packetized memory (not shown), which normally does not include a separate address bus and control bus. The processor 412 is also typically coupled to cache memory 440 through the processor bus  
10 414.

The computer system 400 also includes one or more input devices 434, such as a keyboard or a mouse, coupled to the processor 412 through the system controller 420 and the processor bus 414. Also typically coupled to the processor 412 through the system controller 420 are one or more output devices 436, such as a printer  
15 or a video terminal. One or more data storage devices 438 are also typically coupled to the processor 412 through the system controller 420 to allow the processor 412 to store data or retrieve data from internal or external storage media (not shown). Examples of typical storage devices 438 include hard and floppy disks, tape cassettes, and compact disk read-only memories (CD-ROMs).

20 From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.